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The Problem

PAST experience with cuttings in old-growth northern hardwoods has demonstrated that the primary regeneration problem is to obtain a large proportion of desirable species of good quality. Regardless of method or intensity of cutting, the total amount of reproduction usually is adequate. Second-growth stands are a different story: this report pertains only to old-growth.

The regeneration that comes in after cutting in old-growth stands comes from one or both of two sources: (1) advance reproduction that was already present at time of cut-

ting; and (2) seedlings and sprouts that originate soon after the cutting.

But often much of this young growth consists of species that have no economic value, such as pin cherry and striped maple. Other common species--aspen, beech, and red maple, for example--are much less in demand than the highly desirable sugar maple, yellow birch, paper birch, and white ash. Obviously techniques for controlling the species composition of the regeneration are essential for the most profitable long-term management of northern hardwood forests.

The Study

As part of a comprehensive study of cutting methods in old-growth stands on the Bartlett Experimental Forest at Bartlett, New Hampshire, regeneration records for periods ranging from 10 to 15 years have been obtained for the various cuttings. Those records are the basis for this report.

The stands included in the study were fairly uniform. They ran strongly to beech: this species accounted for more than 60 percent of the basal area. Yellow birch and sugar maple together made up 20 to 25 percent of the basal area. Red maple, paper birch, white ash, red spruce, and hemlock occurred as minor components of the stands. Many of the larger beech, sugar maple, and yellow birch were overmature and defective wolf trees. However, high-quality stems of these species were present in the smaller sawtimber and pole sizes.

Despite the predominance of beech in the overstory, more than half of the advance reproduction[1] was sugar maple; a quarter or less was beech. Most of the other young stems were striped maple. Several small groups of red spruce and hemlock reproduction were present, but they made up only a very small part of the total.

[1] Stems more than 1 foot high and less than 1.5 inches d.b.h.

Experimental Cuttings

Three different methods of cutting were used over a 6-year period.[2]

1. Clear-cutting (22 acres). Hardwoods were cut to a minimum d.b.h. of 1.6 inches, softwoods to a minimum of 4.6 inches, culls included.

2. Selection cutting[3] (25 acres). About one-third of the basal area was removed in trees of all sizes down to 1.6 inches d.b.h., either as single trees or groups of two or three. This was an improvement cutting, to remove low-value trees and culls.

3. Patch cutting (100 acres). Thirty patches of 0.1 to 0.6 acres each, totalling 10.5 acres, were clear-cut. Hardwoods were cut to a minimum diameter of 1.6 inches, softwoods to a 4.6-inch minimum. Patches were located to include a maximum proportion of mature or overmature trees within the boundaries.

Regeneration
Milacre Plots

Before the experimental cuttings, milacre plots were established systematically on all three areas. Approximately 2 percent of the clear-cutting and selection areas was sampled and 5 percent of the area in patches. All advance reproduction between 1 foot high and 1.5 inches d.b.h. was tallied individually by species and 1-foot height classes on each milacre before cutting. Considering all three cutting areas, advance reproduction over 1 foot high was present on 90 percent of the milacres, and 66 percent had advance reproduction at least 3 feet high.

These same milacres were re-examined 10 to 15 years after cutting. The species and height of the one tallest

[2] Jensen, Victor S. Suggestions for the management of northern hardwood stands in the Northeast. Jour. Forestry 41: 180-185. 1943.

[3] Gilbert, A.M., Wilson, R.W., Jr., and Hutnik, R.J. Growth behavior of northern hardwoods after a partial cutting. Jour. Forestry 53: 488-492. 1955.

potential crop tree were recorded for each milacre, provided that the tree was at least 6 feet high (selection and patch cuttings) or 0.6 inches d.b.h. (clear-cutting). Striped maple and pin cherry were not considered as potential crop trees even though some were overtopping more desirable species. It is believed that these temporary species do not seriously retard the development of the potential crop trees.[4]

Consequently for each milacre there is a record of (1) the species and heights of the advance reproduction before cutting, and (2) the species and height of the tallest potential crop tree 10 to 15 years after cutting. These data serve as the basis for evaluating the effects that cutting method and advance reproduction have exerted upon species composition of the current regeneration.

Method Of Analysis

The milacre plot records were sorted and re-sorted according to cutting method and presence or absence of advance reproduction. Within each combination, the number and proportion of the milacres currently stocked with a potential crop tree were determined. Of those that were stocked, the percentage of the milacres stocked with each species was calculated. For convenience, species were grouped into three tolerance classes: *Tolerants* (beech, sugar maple, eastern hemlock, and red spruce); *Intermediates* (yellow birch, red maple, and white ash); and *Intolerants* (paper birch and aspen).

Treatment differences have been tested by the standard chi-square test for enumeration data; for differences designated as significant, P = 0.05 or less.

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[4]Longwood, F.R. Why release young maple from pin cherry? Lake States Forest Expt. Sta. Tech. Note No. 360. 2 pp. 1951.

The Results

Effects Of Cutting Method

Results of the milacre tally confirm our earlier statement that adequate reproduction is usually obtained in old-growth northern hardwoods of New England following any method or intensity of cutting. The percentage of milacres currently stocked varies from 89 percent on the clear-cutting to 67 percent on the selection-cutting area (table 1). That certainly can be considered adequate stocking.

Although adequate total stocking is present on all three cutting areas, species composition of the regeneration varies considerably (table 2). Where selection cutting was used, 92 percent of the stocked milacres were dominated by tolerant species. Patch cutting resulted in establishment of a good representation of intermediates--34 percent of the stocked milacres--in addition to a high proportion (62 percent) of tolerants. On the clear-cutting, intolerant species dominate 38 percent of the stocked milacres, tolerants 43 percent, and intermediates 19 percent.

These figures suggest a rough rule-of-thumb on the make-up of reproduction: selection method, all tolerants; patch cutting, tolerants and intermediates in proportions of about 2 : 1; clear-cutting, all tolerance groups present in proportions of 2 : 1 : 2.

Table 1.--Milacres currently stocked with potential crop trees, by cutting method and condition of advance reproduction

Cutting method	Where advance reproduction was--						Difference	Both conditions	
	Present			Absent					
	Total	Stocked		Total	Stocked				
	No.	No.	Percent	No.	No.	Percent	Percent	No.	Percent
Clear cutting	258	232	90	16	11	69	21	274	89
Patch cutting	417	367	88	87	72	83	5	504	87
Selection cut	519	348	67	37	14	38	29*	556	65
All	1,194	--	79	140	--	69	10	1,334	78

*Significant at 5-percent level.

Table 2.--Species composition of currently stocked milacres, by tolerance group and cutting method

Tolerance group[1]	Clear cutting	Patch cutting	Selection cut
	Percent	Percent	Percent
Tolerants	43	62	92
Intermediates	19	34	7
Intolerants	38	4	1

[1]Species included in each tolerance group:

Tolerants: Beech, sugar maple, eastern hemlock, and red spruce.

Intermediates: Yellow birch, white ash, and red maple.

Intolerants: Paper birch and aspen.

Table 3.--Species composition of currently stocked milacres by tolerance group, cutting method, and presence or absence of advance reproduction before cutting, in percent

Tolerance group	Clear cutting; advance reproduction--			Patch cutting; advance reproduction--			Selection cut; advance reproduction--		
	Present	Absent	Difference	Present	Absent	Difference	Present	Absent	Difference
Tolerants	43	36	7	66	44	22*	94	72	22*
Intermediates	19	18	1	31	49	18	6	21	15
Intolerants	38	46	8	3	7	4	--	7	7

*Significant at 5-percent level.

Effects Of Advance Reproduction

The presence or absence of advance reproduction before cutting had an appreciable effect on both total current stocking and species composition. Current stocking is higher where advance reproduction was present (table 1). This relationship is significant, however, only on the selection-cut area. Here 67 percent of the milacres are currently stocked where advance reproduction was present before cutting, but only 38 percent where advance reproduction was absent.

As would be expected, presence of advance reproduction, which is primarily of tolerant species, resulted in a higher proportion of tolerants in the current stocking (table 3). On both the selection and patch-cutting areas this relationship is significant, but it is not on the clear-cutting. Here the effect of the tolerant advance reproduction

on current species composition probably has been masked by the rapid invasion and growth of intermediate and intolerant species.

Beech And Sugar Maple

Analysis of the milacre data revealed striking differences between sugar maple and beech in behavior of regeneration under all three cutting methods. On the patches and clear-cutting, however, much of the beech is believed to be root suckers that will not develop into high-quality sawtimber. Consequently the following comparisons apply only to the area cut by the selection method where root suckering is at a minimum.

The percentage of milacres now stocked with sugar maple and beech was strongly influenced by three conditions of the advance reproduction before cutting:

1. *Presence.* Where advance reproduction of sugar maple had been present before cutting, the percentage of milacres now stocked with sugar maple is 10 times as much as where advance reproduction was absent. Current stocking of beech in a similar comparison was only about 3 times as much on the milacres that had carried advance reproduction.

2. *Height.* Where sugar maple advance reproduction was more than 4 feet high before cutting, the proportion of milacres now stocked with sugar maple is more than 5½ times as much as where it was only 1 to 2 feet high. In a similar comparison for beech, current stocking on milacres that had the taller advance reproduction is about 2½ times as much as on those that had the shorter advance growth.

3. *Density.* Where the number of advance seedlings of sugar maple was 10 or more per milacre before cutting, the percentage of milacres now stocked with sugar maple is 4 times as much as where the number was 1 to 3 per milacre. Current beech stocking is 2 times as much in a similar comparison.

Discussion & Summary

Under intensive management, the choice of a cutting method in old-growth northern hardwoods should be based on several considerations. One of these is the condition of the stand; i.e., the location, quality, and age of the merchantable trees. Another important consideration is the effects that cutting method and the character of the advance reproduction have on the species composition of the reproduction that develops after the cutting. As regards those effects, conclusions may be drawn from the study as follows.

1. *General effects.*--The selection method favors tolerant species--chiefly beech and sugar maple--almost exclusively. Patch cuttings of 0.1 to 0.6 acre are conducive to establishment of the intermediate yellow birch and white ash among the tolerants in proportions of roughly 1 : 2. Clear cuttings in areas of 5 acres or larger permit establishment of the intolerant paper birch and aspen; here there will be intolerants, intermediates, and tolerants in proportions of roughly 2 : 1 : 2.

2. *Effects of advance reproduction.*--With patch and selection cuttings, the presence of advance reproduction--largely tolerant species--results in significantly larger proportions of tolerants in the dominant reproduction 10 to 15 years later. Conversely, absence of advance reproduction favors establishment of larger proportions of intermediates and fewer tolerants. These effects are not evident on clearcuttings.

3. *Differential responses of beech and sugar maple to variations in advance reproduction.*--Considering selection cutting only, we find that sugar maple regeneration after cutting is very markedly favored, not only by being present before cutting, but also by increased height and increased density in the advance reproduction. Beech responds to these factors in the same direction, but to only one-third to one-half as great degree as does sugar maple.